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WATER MANAGEMENT

Outline analysis of water management problem area

Sudano-Sahelian Zone

Special Sahelian Office

WATER MANAGEMENT

(a) The problem

The severe droughts of recent years, and especially that of 1973 have clearly demonstrated that under a lasting water shortage situation, the Sahelian countries face a collapse of their fragile economy, a degradation of their environment, of their social structures and services, and losses of human life and of livestock.

Except for a limited modern urbanized-industrial sector, the entire economy draws on a small number of meagre ancestral resources: (a) an always overgrazed and sometimes parched or sterile pasture-land; (b) a degraded, sparse, and vanishing forest; (c) a precarious agriculture, the victim of uncertain rainfalls and river-floods. Moreover, surface water streams, ponds and shallow wells often dry up between rainy seasons, thus worsening - tragically at times - water supply conditions both for population and livestock.

A large fraction of the economy, and of the population therefore lives a marginal existence. Several of these countries are amongst the poorest of the world and one of them, Upper Volta, may now have the lowest per capita income in the world.

It would be erroneous, however, to think that a lack of water resources is responsible for the low and precarious standard of living of the population. In fact, in the populated areas, a large water potential is available for development in the six countries, both with respect to surface streams and underground water.

The main drainage systems cover a substantial fraction of the area. The Senegal River system, in its lower section, conveys some 22,000 million m^3/year on the average; the Niger River brings into its inland delta - between Mopti and Timbuktu - some 70,000 million m^3/year, of which 30,000 million m^3 flow at Niamey. The Logone-Chari floods into Lake Chad amount to 40,000 million m^3/year. If only one quarter of these resources were available for the countries concerned; 1/ more

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1/ Considering that other countries are also entitled to the use of these waters.

than 1,000 m^3/year could theoretically be available for each inhabitant: that is more than the highest consumption rate for industrialized countries. 2/

2/ In order to view this problem in perspective, it may be pointed out that the total vast area covered by the six countries of the Sahelian zone is 5,172,000 km^2. More than half of the area is occupied by deserts (with less than 60 mm/year of rainfall), with almost no population. The southern part of Senegal, Upper Volta, and Chad fall within the Guinean climatic zone where water problems are much less acute owing to the relatively adequate rainfall (more than 1,200 mm per year).

The populated arid area in the six countries as a whole covers about 2 million km^2.

It must also be noted that the sedentary population are mostly gathered along main river courses, which even in their natural state offer perennial water supply.

The supply could, of course, be considerably improved by the regulation of the river flows. To give an idea of the possible impact of such flow regulation, if it is assumed that the population is concentrated within a band of 5 km on either side of the river bank, it is possible to calculate the approximate average annual amount of water available per square km as a result of regulation. This can then be evaluated as an annual average depth of water to be compared with rainfall availability.

For the Senegal river downstream from Bakel, the average maximum regulated discharge would be 770 m^3/s. Assuming that 200 m^3/s must be saved in the lower course (for navigation and salt intrusion control), 570 m^3/s would be available for agriculture and dwellings along a reach of roughly 600 km, i.e., an area of 6,000 km^2. This means an average available water depth of 3,000 mm/year (to be compared with the 600 mm annual rainfall in the area).

The river Niger at Koulikoro (average discharge 1,545 m^3/s) increased by the Bani river (average discharge at Douna 731 m^3/s) provide altogether 2,276 m^3/s, to the Sahelian zone. Assuming that needs downstream from Niamey require a flow of 1,000 m^3/s, 1,276 m^3/s would be available for the supply of the arid zone along the approximately 1,500 km long stretch (15,000 km^2). This would be equivalent to an average water depth of 2,600 mm/year (compared with 500 mm available from rainfall).

The Chari river at Nousso (average discharge 950 m^3/s) and the Logone river at Lai (average discharge 541 m^3/s) feed into the Sahelian zone a total of 1,491 m^3/s. From this amount 1,000 m^3/s must be saved for the annual refilling of Lake Chad.

In addition to the 600 km long river course along the Chari river and 300 km along the Logone river, the area directly affected by this water supply includes the Lake Chad river banks, roughly 600 km in length. The total area involved would thus cover an area of 12,000 km^2, which could receive annually a water depth of 1,280 mm (compared with 400 to 1,000 mm/year average available rainfall).

The figures show that, using the available water from the three large river systems of the Sahelian zone, it would be possible to manage water resources in an efficient manner within bands 10 km wide along the main river courses. The total area involved represents 33,000 km^2 (3,300,000 hectares) which is, of course, far more than can be used for agriculture. This would receive an average discharge of 2,337 m^3/s, i.e., 70,000 million cubic metres, or an average depth of 2,100 mm per year.

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Ground water resources potential is also enormous. For the crystalline basement areas of Upper Volta it has been estimated that the yearly replenishment by rainfall exceeds by 10 to 100 times the present needs of the population (the rest being lost to the atmosphere by evaporation), while in the vast sedimentary basins of Chad, Niger, Mali and Senegal-Mauritania, the three aquifer systems of "Continental Intercalaire-Hamraden", "Maestrichtien" and "Continental Terminal" hold reserves estimated at several hundred billion m^3, possibly reaching 1 trillion (10^{12}) m^3.

On the basis of these figures, it is apparent that in the areas which have, or are likely to have, the major concentrations of population the lack of water resources is not the real problem. The main problems lie in the lack of application of an integrated water policy which may take into account, inter alia, the uneven distribution of rainfall and water resources over space and time, the limited number of permanent surface streams and water bodies, the cost of water structures - the countries being short of cement and iron - and the high cost of ground water exploration and development. It is not necessary to dwell here on the well-known bottle-necks for development, which are common to countries having a per capita income per year below, and sometimes well below, the 100-dollar mark. It is also well known from past experience that water resources development requires, in such countries, technically qualified manpower, technologies, equipment, capital investment and other resources which are only available locally in small measure.

Thus, the cost of water resources development in this largely land-locked subregion is such that only a limited number of complex projects can be considered economically feasible. On the other hand, rational water resources development is the key to improved and modernized economies based on (i) improved cattle breeding, and where feasible irrigated agriculture; (ii) the creation of industries related to agricultural and non-agricultural products; (iii) the exploitation of mineral resources; and (iv) the development of cheaper means of transportation. Such water resources must be made available at prices which are economically acceptable in relation to the value of the goods produced.

In conclusion, if it is true to say that present availability of water is currently one of the main limiting factors for development in the area - if not the main or only one - and that supplementary water resources are available in large quantities, it should also be stressed that the costs required to develop these resources require a careful appraisal of the social and economic benefits which are expected from future water use projects. Such an appraisal should also consider the extent to which in desert areas traditionally irrigated agriculture, with its highly water-intensive applications, might usefully be replaced by more water-efficient activities such as pasture and livestock development, primary industries, mineral development and tourism. This appraisal, in turn, then should be made within the over-all framework of a strategy for the development of the region, which should include, as a first priority, the definition of a water policy and its expression in terms of implementing a comprehensive water management programme for the Sudano-Sahel area.

It is obvious that political and social pressures do not make it possible to await the formulation of a comprehensive long-term water resources development plan before taking urgently needed action to relieve existing water shortage problems. These, as will be seen later, should be viewed, therefore, in a short-term (three years) and long-term perspective.

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(b) Significance of the water sector to the economy and relationship to other economic sectors

It is quite apparent that for any development project in the area, water resources development is involved as an essential, if not key, factor. Water resources availability is in fact both a limiting factor and an incentive for development plans.

In the agricultural sector availability of water would change the present condition of traditional agriculture, closely tied to the occurrence of rainfall. Limited irrigation provided at the right time, for instance after germination, and before harvesting, would increase the yield of most fodder and cash crops. Small-scale irrigation of this type can be provided with limited resources, through direct pumpting from wells or rivers.

Cultivation of industrial crops, on the other hand, where technically and economically warranted, needs perennial irrigation over large areas, at an acceptable cost. In this case, the necessary control of surface water resources is required, and regulation and storage behind dams of various sizes. A limited number of irrigation projects can use ground water. In specific instances high value cash crops can bear the relatively high cost of water thus provided.

In the pasture, livestock and wild life sector an optimal distribution of water points, and a proper selection of specifications for well construction and water extraction devices has to be arrived at to ensure that herds and wild animals will neither perish from thirst nor overgraze certain areas in their displacements. Such conditions are far from being reached at present.

An important trend at present is to associate agriculture and livestock activities. Large-scale cultivation of irrigated fodder is a necessary condition for standard quality livestock feeding. Waste from some agro-industries may be used as food for animals. On the other hand, manure is necessary for high yield industrial agriculture. Such agro-industrial complex can only be organized in areas where water is available in great quantity.

Creation of industries derived from agriculture and livestock is a direct consequence of relatively large-scale development of the two sectors indicated above. Important aspects will also be availability of water, low cost transportation and power, which suggest that their location might be envisaged along large rivers, where the industrial crop schemes and cattle fattening fodder schemes are likely to be concentrated.

Fisheries already represent a considerable proportion of the national income of the Sahelian countries. The question has been raised whether the regulation and control of large rivers for other purposes would be beneficial for fish production. On one hand, storage dams of several billion cubic metres apparently constitute ideal conditions for fish growing. On the other hand, the variable level of artificial lakes, and the reduction of inundated areas downstream from the dam owing to flood limitation may create serious difficulties. For the

Selingue scheme, the only benefit expected from the dam construction in Mali, would be the availability of fish nearer to the market places than the traditional fisheries.

In the energy sector, it is apparent that hydro-power offers at present the cheapest prospects. No fossil fuels have been found so far in this largely land-locked area; geothermal potential seems to be much less promising than in East African countries. Radio-active minerals seem to be in modest supply and in any case their entire production is exported and subsidized due to high mining costs. Extensive studies were made on solar energy, especially in Niger; however, practical applications still appear to be quite limited. Thus the main potential for energy appears to be in harnessing rivers for hydro-power; development appears to be the only broad possibility for developing local resources. This consideration is related to the industrial sector which cannot expand if it relies on imported, and thus precarious and expensive energy.

In the transport sector, river navigation offers some interesting possibilities, considering the relatively good natural conditions and the low cost for river transport. However, the expansion of river navigation in the sense of an increase in the time period during which navigability of rivers is feasible, of ship tonnage, and of length of navigable waterways also requires a control of streamflow, and the construction of large-scale water management works. Road construction in the Sahel requires large amounts of water (up to 800 m^3/km for compaction alone).

The mining development sector needs water at various levels of exploitation, treatment and transportation.

In desert or arid areas water has sometimes been an obstacle to mineral ore exploitation, in connexion with providing a minimal supply for personal and for preliminary dressing or concentration on site. For example, the mine of Tambao in Upper Volta for manganese exploitation, is expected to require 1,100 m^3/day and the cement factory of Tin Hrassan, 1,200 m^3/day. In Mauritania, the copper mine of Akjoujt requires 6,000 m^3/day. These relatively small amounts of water can be supplied either from ground water or by artificial ponds, or pipelines (Akjoujt is supplied by a 115 km long pipe). Metallurgic complexes would require a much more considerable discharge.

Low value mineral ore can only be exploited if its transport to the refining plants (often far from the mine-sites in relation to power and fuel availability) can make use of waterways. For example, bauxites along the Faleme River, near Kenieba in Mali could perhaps be exploited if this river, and the Senegal River were navigable all year round. The same would apply to the copper ore in the south-east region of Upper Volta.

Of course, a prerequisite for waterway transportation is the regulation of the waterflow in the large rivers.

The health and well-being of the population are closely dependent upon the availability of good quality drinking and domestic water in sufficient supply.

The present distribution of the population in this region, as vast as Western Europe, is closely related to present local availability of water supply, often precarious and unsatisfactory in terms of quality and quantity. Improvement of water supply conditions can be considered a major incentive for maintaining population groups in certain areas and moving others to areas where better prospects for economic development can be expected, through the development of new resources. In fact, social aspects for water development in this part of the world are particularly important and the benefits of the projects should not be assessed using conventional economic standards only. In fact, in some cases, such as the construction of simple water wells in rural areas where the issue is the survival of human communities, this general remark is particularly relevant.

In short, water resources are closely related to the entire socio-cultural structure of the area. This observation is valid for future development, as it was in the past, and under present emergency and short-term conditions.

(c) Past achievements

Prior to 1961, the six countries were part of the French "community" and most, if not all, of the water development projects involved French techniques, personnel and capital.

Surface water - The major project by the French Government, prior to the Second World War, consisted in the creation of the "Office du Niger" in Mali for irrigation. It was a project which involved the construction of the first major dam in the area at Markala. Other very large irrigation schemes, mostly for rice cultivation, include the "Casier Richard Toll" along the Senegal River; the "Casier de Baguineda" in Mali along the Niger River; the "Casier de Bongor" in Chad; and the "Casier de Yagoua" in Cameroon along the Logone River; and finally, the "Polders" along the Lake Chad north shore.

These activities, among many others, have been carried out by the FAC and the FED. IBRD has also recently co-operated in reviving old projects, such as the Casier de Yagoua (Semry) or helping construct new ones, such as the Sategui-Deressia scheme on the Logone.

Studies of specific dam sites have been undertaken on all the large rivers. A preliminary inventory of the most suitable sites has been available for many years, and has been supplemented more recently by more sophisticated studies financed by UNDP. These projects, which by no means exhaust all the possibilities for surface water feasibility studies on the major rivers, include:

(i) In the Senegal river basin - two projects for the reconnaissance and selection of dam sites best suited to the regulation of the river in Guinea and Mali;

(ii) In the Niger river basin - a feasibility study for a dam at Senlingue on the Sankarani River;

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(iii) On the Logone river basin - a project for a preliminary feasibility study of the regulation of the river through two-stage reservoirs at Kouman and Gore.

It is interesting to give some indication as to the cost of water which is provided by such large reservoirs. In the report for the Senegal River study, for instance, and assuming that the total discharge will be used, the unit cost of 1 m^3/s varies from 15 US mills/m^3 (regulation of 100 m^3/S) to 7 mills/m^3 (regulation of 400 m^3/S). Further details are provided under annex II.

Water supply storage and distribution schemes have been developed, such as the storage pond for the supply of Ouagadougou and the lac de Guier for the supply of Dakar. Also a number of small ponds for the water supply of villages and for small irrigation schemes were built, particularly in Upper Volta. Hydroelectric power plants have been installed, such as the Felou scheme, near Kayes, on the Senegal River; and Sontuba, near Bamakro on the Niger River.

The inventory of available surface water has been conducted systematically in all the countries of the region: meteorological surveys were done by ASECNA and a hydrological study by ORSTOM. The latter included the installation of hydrological stations in the main streams and a study of run-off, evaporation and infiltration. Important lakes have also been studied. Among the ORSTOM publications are included monographs on the Senegal, Niger, Chari and Logone Rivers and the UNESCO monograph on Lake Chad may be referred to. In addition to the collection and processing of all available data in these basins, the documents provide the necessary hydrological characteristics for further planning of water resources development.

From an institutional point of view, management functions have been performed as follows: from 1950 to the independence of Senegal, Mauritania, Mali, Upper Volta and Niger, the "Service de l'Hydraulique de l'A.O.F." carried out a considerable amount of activity in the inventory and promotion of new works. However, surface water projects were mostly managed by local bureaux of "Electricité de France, inspection des services Outre Mer". In Chad a "Bureau de l'eau" has existed since 1953; this centralized all ground water and surface water research and development studies.

Since independence, these countries have preserved some co-ordinated functions in the water resources field. In Upper Volta the service is well established and efficient.

Specific organizations have been created for the development of large river basins:

(i) For the Senegal - OMVS (Organisation pour la mise en valeur du fleuve Senegal) with headquarters in Dakar;

(ii) For the Niger - the "Niger Committee", the secretariat of which is situated in Niamey;

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(iii) For the Logone - "Commission mixte Tchad-Cameroun".

These organizations have been in existence over the last 10 years. Although their activities have been rather limited and largely of a study and advisory nature, they have been a useful forum for the collection and exchange of information among member States, which have certainly been made increasingly aware of the co-operation problems involved in the development of large, international river basins.

Ground water - With respect to ground water, after the creation of the Hydraulic Service for West Africa in Dakar (1950), a large programme of ground water reconnaissance and inventory of water points was started. More than 20,000 water points were visited, located on maps and described in detail on index cards; thousands of water samples were analysed. Hydrogeological maps were prepared at various scales and sometimes in full detail. This type of operation was pursued after independence. At present (1973) French bilateral assistance still provides hydrogeologists and other ground water experts to all six countries (for a total of about 10 experts).

In all six countries ground water conditions are fairly well known. An abundant bibliography is available (more than 1,000 titles including major reports on open file). Detailed investigations including geophysical prospection, drilling and pumping were concentrated in areas where major cities and industrial and mining installations required large amounts of water, such as Nouakchott and Nouadhibou (the two major cities of Mauritania), Dakar, the mining sectors of Fort Derick and Akjoujt (Mauritania) and Arlit (Niger).

Large-scale investigations, including geophysical prospection and drilling were made for vast hydrogeological units such as the coastal sedimentary basin stretching from Senegal to Mauritania, the "Detroit Soudanais" (sedimentary area comprised between Adrar des Iforas and Gourma in Mali, the Niger basin east of Niamey, Chad).

Small-scale investigations were made for localities mainly situated in crystalline basement and sandstone-scale areas such as Aioun El Attous (Mauritania), Goudiri-Kidira (eastern Senegal); Kongolikan, Kari, Boni (Upper Volta); Ouaddai, Pala (Chad).

Several thousand modern wells have been built since 1950. This effort, undertaken under the French administration, was pursued and expanded through actions of the French bilateral assistance organization ("FAC"), and of the European Fund for Development, (FED). It was first applied to sedimentary areas and especially to the "Continental Terminal" aquifer, a relatively soft and high-yielding formation.

It was further applied to the crystalline basement formations and their hard rock sedimentary cover, but the needs which remain to be satisfied are very large. They are estimated at 20,000 wells for the six countries. The present rate of construction is about 500 to 600 modern wells per year (including about 150 in

Upper Volta and in Niger, and about 50 in Chad and Mauritania). This would mean that at present levels, more than 30 years would be necessary for bringing the programme to completion. Meanwhile, over such a period the population would have doubled and the needs would have increased accordingly.

Deep aquifers which hold large quantities of water (often under confining conditions, implying that artesian flowing wells are feasible) were not explored on a large scale because the social and economic benefits of the operation appeared doubtful.

About 150 deep boreholes were drilled in Senegal to create water points for village water supply and livestock; about as many in Niger; less than 100 in Mali and Chad; a small number in Mauritania and Upper Volta.

Drilled wells cannot be operated without the use of pumps, which wear out fast and easily break down for various reasons in these countries. For instance, out of some 30 pumps installed by USAID in Senegal only two or three were in working condition after four years. The cost of drilled wells and their operation is very high; the cost of pumped water under the most favourable conditions can be assessed at approximately 20 CFA francs per m^3 (that is 10 US cents per m^3, or $120 per acre-foot). In Northern Niger it goes as high as 100 CFA francs per m^3 (50 US cents per cubic metre). This practically precludes the utilization of ground water for irrigation, except in a limited number of very special cases for growing high value cash crops.

In addition to FAC and FED assistance, the following bilateral organizations have provided assistance: USAID, through the drilling and pumping programme already mentioned for Senegal and assistance for the construction of hand-dug wells through the Peace Corps in Upper Volta, Niger and Chad; Chinese assistance to Mauritania (ground water development for Nouakchott water supply); Federal Republic of Germany assistance to Senegal, Mali, Niger (urban water supply, ground water exploration and development in the Gourma); USSR assistance to the National Drilling Company of Mali (SONAREM); Hungarian bilateral assistance to Mali in ground water studies; Canadian, Swiss and Danish assistance for Niger.

As regards the United Nations system, five main types of funds have been involved: (a) United Nations Development Programme for pre-investment studies; (b) Regular programme funds of United Nations agencies for technical assistance; (c) UNICEF for village water supply in water-short areas; (d) World Food Programme in the form of food rations for workers constructing wells; (e) World Bank funds for investment.

In an annex, a listing of all the UNDP sponsored water projects for the six countries is presented. All projects include pre-investment and training objectives. In a number of them, a certain amount of investment is included in the form of a pilot development programme for well or bore-hole construction. Institutional aspects are also considered. Most of the projects fall into the following categories:

- River or lake basin management studies (mainly intercountry projects) and dam site studies;

- Ground water exploration and pilot development, mainly for rural water supply;

- Hydrology and flood studies;

- River navigation studies.

As far as ground water exploration and development are concerned, UNDP projects had, or will have, among their achievements:

- The preparation of a future programme of well construction to be presented to potential investors;

- The strengthening of government water services through the execution of well drilling, well digging, and the delivery of scientific and other equipment;

- The construction or the drilling of a substantial number of production wells under most difficult conditions;

- The training of local personnel, including hydrogeologists and their assistants, geophysical prospection teams, drilling teams and chemists.

World Bank programmes for ground water development mainly include the financing of well digging brigades (Mauritania, Chad, Upper Volta) and of well construction programmes to be carried out by contractors.

Conclusion

In spite of past efforts, very few development projects for harnessing rivers or developing hydro-power or large-scale irrigation has been completed as yet. A number of cities, both large and small, do not have enough drinking and domestic water at their disposal; at the present rate more than 30 years would be necessary to satisfy most of the need for well construction in rural areas. It has, therefore, to be concluded that a major breakthrough has to be made in water resources development for the subregion. Such an effort implies a massive injection of expertise and capital, but above all, a major undertaking in water resources development planning. By and large, available data are sufficient to do this for the principal river basins in the subregion, and in particular, to take decisions on the most suitable dam sites. Such a selection has already taken place at the sub-basin level for the Niger and Senegal river basins within the framework of UNDP projects already referred to. Final feasibility studies will, however, still require geotechnical investigations and more detailed economic studies.

In the following paragraphs a tentative, preliminary outline for further action is presented.

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(d) Objectives and targets for the future

Ideally, a clear definition of a water policy in the region and a comprehensive water resources management programme would aim to achieve the following objectives:

- An optimization of the use of surface water resources through multipurpose projects involving flood control and flow regulation, irrigation hydro-power for agro-industries and ore processing (if not metallurgy). This may require the resettlement of some population along the main rivers;

- An improvement of water supply conditions of rural areas through a massive programme of well digging and drilling, and the creation of small surface water storage facilities (small dams);

- An improvement of water supply conditions in larger cities;

- An optimization of the use of pasture land through proper distribution of the water points and a proper design and construction of wells (and water extraction devices);

- A substantial increase in river navigation traffic and tonnage to be co-ordinated with the use of other means of transportation;

- A combined utilization of mineral and water resources in land-locked areas, such as the Liptako-Gourma;

- Wherever possible, a combined and optimized utilization of water resources from various origins for multiple-purpose use;

- An efficient and economic system for the maintenance of all water installations and equipment.

Any comprehensive water management programme must have as a point of departure a data base on which to base policy decisions and short- and long-term work programmes. Such a data base might be collected within the framework of a water resources department of the PISC or by an ad hoc intergovernmental water resources institute. The type of information which would be required might include:

- The present and future assessment of water and energy needs, assuming various trends for the country's economy;

- Inventory of all water resources from any origin (rainfall, river run-off, ground water, potential for cloud seeding, geo-pressure zones) and review factors that will affect water utilization (evaporation and related meteorological parameters, infiltration);

- Survey of physical and technical parameters related to water storage, extraction, distribution, and rough evaluation of their cost;

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- Review of agencies, laws and regulations relating to water resources sector with a view to improving or completing the institutional base;

- A collection of all available existing data records, studies and feasibility reports relating to water resources within the region for the establishment of a data bank.

Once this type of data base were available, it would become possible to take up for discussion some important policy issues. These might include:

- Circumscribing areas with limited water potential (and identifying their maximum acceptable livestock carrying capacity) from those with more abundant water resources, with a view to taking decisions on the allocation of development funds;

- Investigating the desirability of and whether any possibilities exist for diverting water to water-short areas from relatively water-rich ones;

- The degree to which, and in which way, Governments should favour poler development along large rivers and in areas where ground water resources are available in adequate quantities for human and livestock needs;

- What short and long-term prevention measures should be taken to avoid a recurrence of drought, and what emergency procedures may be set up on a stand-by basis if it does (primarily provision of shelter, food and water at strategic locations).

As indicated earlier, the present reality requires urgent action, both of a short-term and longer-term nature.

Proposals for a short-term programme in the field of water resources development

This could relate to six principal areas: (a) ground water exploration; (b) maintenance of existing wells and development of new wells; (c) feasibility studies for surface water development; (d) construction of dams for which studies were completed; (e) use of non-conventional sources of water, and (d) establishment of an appropriate institutional arrangement.

Ground water exploration - A massive effort is to be made for the selection of potential sites for wells in the crystalline basement areas and in the deep sedimentary basins. This requires extensive operations involving field reconnaissance, air photo interpretation, ground geophysics, water analyses, drilling, pumping, assessment of water resources potential through the use of digital modelling (computer studies).

To minimize the costs of these investigations which are to be carried out in rural areas and small towns suffering from an acute water shortage and in areas with mineral resources potential, the operation should be designed on a large scale and multinational basis, and be preceded by consultant work to identify

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methods and equipment which would facilitate reaching the targets with the shortest delay, at minimum cost and with the best results. This would apply especially to remote sensing, ground geophysics and drilling.

Several geographical areas have already been identified for such work and especially areas in Mauritania, Niger and Mali.

Maintenance of existing wells and development of new wells - For the development of ground water resources, large amounts of capital are necessary. Funds required to carry out the programme for rural well construction (20,000 wells) may amount to $150 million to $200 million, if the work is to be done by contractors. On a self-help project basis these costs could be reduced by 50 per cent. It should be noted that these sums do not include pumping installations. The situation is quite different for programmes involving extensive drilling operations and the installation of pumps. These require the use of expensive equipment (drilling rigs), pumps, motors and supplies (screens). Maximum efficiency and a reduction in costs could and should be achieved through the organization of a multinational corporation, either within or outside the intergovernmental secretariat, for ground water development to achieve a centralization of programmes and objectives. Within this framework, maintenance activities for existing wells should be established within the corporation with the necessary competence and funds for the operation of existing and new facilities.

Feasibility studies for surface water development - It appears necessary, from a data base point of view and in order to clarify investment needs, to have as comprehensive a picture as possible of the development potential for all sources of surface water in the subregion. In some instances, additional studies are required to complete existing data for a feasibility project evaluation. In others, studies have to be started from scratch. Among those for which studies require completion, the following may be listed:

(i) The planning of the Senegal River development is well advanced from a technical point of view, but should be revised when more accurate economic data, currently being obtained, is available;

(ii) In the Niger river basin, apart from the study for the Selingue dam (see below) between the Guinean border and Segou, work remains to be started in the stretch between Segou and Niamey. The crossing of the Cuvette Lacustre, the défilé de Tossaye, and the waterway from Tossaye to Niamey which is now interrupted by difficult rapids, would justify studies for an integrated development which would enhance the value of available resources in the region (cattle breeding, minerals, etc.). Dam sites suitable for irrigation, navigation and hydroelectric energy production have already been surveyed in this connexion;

(iii) The Volta river basin, which includes large tributaries in the Sahelian and Sudano-Sahelian zone also deserves attention from an integrated point of view;

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(iv) The Logone River development has benefited from very preliminary planning so far, and more detailed feasibility work should be pursued;

(v) Survey work could also be usefully initiated on other basins, such as the Komadougou River and the Chari River, both tributaries of Lake Chad.

Construction of dams for which feasibility studies have been completed - Two dams within the region are currently at a stage where the decision to go ahead with construction has, in principle, been taken. These are the Selingue River on the Niger River and the Manantali dam on the Bafing, a tributary of the Senegal River. The FED has decided to finance limited supplementary studies for the Selingue as a last step prior to making a decision on construction. As regards the Manantali project, the Mali Government has decided to seek financial support to initiate this project.

Use of non-conventional sources of water - Artificial rain-making, as a means to produce additional water in specific areas, should not be overlooked. However, it must be borne in mind that this technique cannot be considered ready for routine utilization as yet, especially in this part of Africa where mechanisms for rain formation are still unknown.

The commercial firms which propose rain-making should not be contracted before the advice of competent organizations has been sought and carefully evaluated. One of the principal organizations whose considerable competence has been proven in this field is the Section for Weather Modification of the National Oceanic and Atmospheric Administration (NOAA) based in Miami, United States of America. This organization also has a French counterpart, the Société Météorologique de France.

Experiments on cloud-seeding carried out in Anagadongou in 1967 were inconclusive. Recently, rain-making activities have been subcontracted to an American company by the Government of Niger. The type of information on precipitation patterns, cloud formation, winds, etc. required for a serious weather modification study requires the existence of a viable meteorological network covering the six countries. Early attention to the establishment of such an integrated network would be highly beneficial to the integrated water resources approach envisaged.

A further possibility exists for the exploitation of geo-pressure zones, namely, areas of hot water at great depths under pressure which could give rise to multipurpose application for the production of water, energy and minerals. The search for geo-pressure zones under the sedimentary basins of the region could be undertaken in conjunction with petroleum exploration activities. Such possibilities might usefully be discussed and explored.

Establishment of an institutional arrangement - While acknowledging the existence and important role of the three international river commissions (Senegal, Niger and Chad), a water resources planning bureau appears to be

indispensable to integrate the functions and assist the three commissions. This bureau could be placed within the intergovernmental secretariat or created as an autonomous intergovernmental subregional water resources institute. It should ultimately have responsibility for formulating the long-term integrated water resources development plans for the region, taking into account not only the activities of the three international river commissions, but also those of other technical organizations operating at a national level (with which it should establish close ties). It could, in due course, come to also perform training functions for the water resources technicians of the six countries and undertake specific research activities. International expertise could be utilized by the bureau in the initial stages to assist the permanent staff appointed to it. The proposed ground water development corporation should be intimately associated with the work of the bureau.

In the context of the short-term programme, the bureau should begin assembling and collating information for the data base activities, and set up the necessary field machinery for systematic data collection. It could also assist in drawing up the detailed programme of work, already suggested in the ground water and surface water fields.

One of the important and complicating aspects is that all the large perennial rivers flowing through the five Sahelian countries belong to international basins. The regulating reservoirs will generally not be located in the same country as the ones which establish irrigation schemes benefiting from the regulation. International organization and agreement is, therefore, a vital feature. The river organizations, which fortunately already exist, have insufficient authority for effective control in these matters and some assistance in this respect might stem from the bureau.

Long-term programme - This should primarily consist in the consolidation of the work of the planning bureau with a view to preparing five and 10-year integrated water resources development plans for submission to the member countries. Such plans, which would take into account the proposals and activities of the three international river commissions and the data base information gathered by the planning bureau, should cover a broad spectrum of action programmes in the light of institutional (legal-administrative-organizational), economic, technical and social conditions. An important component of the phasing would relate to the timing for the implementation of new surface and ground water development schemes, and to the financial commitments required. Such proposals would naturally have to take into account government development plans and related programmes for agricultural, industrial and mining activities, power requirements, settlement and resettlement plans, transportation, etc.

ANNEX I

Large-scale UNDP-assisted projects having a water resources phase

(*) modest water components (**) substantial (***) large or exclusive

Project number and title	Executing agency	Date approved	Estimated completion date	Estimated project cost (US dollar equivalent) UNDP	Government counterpart contribution	
CHAD						
Natural resources						
CHD-71-510 Rural water supply	UN	12/72	10/73	215,000		(***)
Rural development of the Ouaddai, Arache	ILO	06/69	08/73	1,004,549		(*)
MALI						
Natural resources						
MLI-67-507 Strengthening government services for ground water exploration and development	UN	06/67	01/74	980,555	416,557	(***)
MLI-68-001 Natural resources development and power	UN	01/69	03/73	188,475		
MLI-70-505 Investigation of the Selingue dam site on the Sankarani River	UN	01/70	07/73	456,700	227,550	
MLI-71-512 A study of a drainage system for Bamako and water supply for selected provincial towns	WHO	01/71	07/74	538,800	165,390	(**)
MAURITANIA						
Natural resources						
MAU-67-502 Strengthening of the ground water service	UN	06/67	03/73	967,845	490,310	(***)
MAU-69-503 Studies for the development of the Gorgol river basin	FAO	01/69	04/73	991,572	193,345	
NIGER						
Development of animal production and water resources in Eastern Niger	FAO	08/64	07/68	877,300		(**)
NER-65-508 Surveys for the agricultural development of the Dallol Maouri	FAO	06/66	11/72	1,240,228		(**)
SENEGAL						
Natural resources						
SEN-68-001 Hydrology	UN	11/68	09/73	55,450		(**)
UPPER VOLTA						
Natural resources						
UPV-63-504 Mineral and ground water surveys	UN	06/63	01/72	1,003,139	692,716	(**)
UPV-71-005 Strengthening of the national hydrological network	WMO	07/71	01/73	35,110		
UPV-72-039 Water and water resources	UN	Starting	1974	300,000		
UPV-72-04 Site of dams on the Volta Noire	UN	Starting	1974	100,000		
Phase I						
Hydrological and railway studies in connexion with mineral development in the north-east	UN	01/69	06/72	1,000,992		(**)

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Intercountry projects in Africa

(*) modest water components (**) substantial (***) large or exclusive

	Project number and title	Executing agency	Date approved	Estimated completion date	Estimated project cost (US dollar equivalent) UNDP	Government counterpart contribution	
RAF-65-052	Feasibility survey for the regulation of the Senegal River 2/	UN	01/65	05/72	958,410	145,000	(***)
RAF-65-053	Feasibility study for the diversion of the Logone River floods 4/	UN	06/65	07/71	354,595	126,400	(***)
RAF-65-061	Hydro-agricultural survey of the Senegal River basin 3/	FAO	01/65	11/73	3,709,800	711,000	(**)
RAF-65-071	Study of water resources in the Chad basin 5/	UNESCO	06/65	05/72	467,798	105,898	(***)
RAF-66-079	Survey of the water resources of the Chad basin for development purposes 5/	FAO	01/66	04/72	2,950,482	123,960	(***)
RAF-66-080	Design of a system of water management in the Upper Senegal River catchment 1/	UN	01/66	09/72	1,109,156	860,000	(***)
RAF-68-554	Ecological research in Africa	UNESCO	03/69	04/72	86,700		
RAF-70-060	Hydrological and topographical studies of the Gambia River basin 2/	UN	01/70	02/74	475,036	179,234	(***)
RAF-70-181	Document centre for the Senegal basin development programme 1/	FAO	01/70	03/72	219,200	71,280	(*)
RAF-70-198	Documentation centre for the Niger Basin Commission 3/	UNESCO	06/70	04/73	175,811	33,741	(*)
RAF-71-147	Planning the development of the Kagera River basin 4/	UN	01/71	01/74	1,038,700	391,000	
RAF-71-252	Institutional support to the Lake Chad Basin Commission 5/	UNDP	06/71	01/74	258,000	250,000	
RAF-71-257	Institutional support to the Organisation des états riverains du Senegal 1/	UNDP	06/71	06/73	119,000	300,000	
RAF-70-179	Flood forecasting and warning system on the Niger River	WMO	01/70	04/73	441,104		(**)
RAF-67-086	Navigability and port studies on the Senegal River	UN	01/67	01/73	1,331,403		(**)
RAF-66-025	Hydrometeorological survey of the catchments	WMO	01/66	01/74	2,597,937		(**)
SEN-73-003	Sahel drought emergency and mid-term ground water assistance in Senegal	UN	07/73	01/77	620,000 6/		(***)
MAU-73-005	Sahel drought emergency and mid-term ground water assistance in Mauritania	UN	07/73	01/77	500,000 6/		(***)
MLI-73-002	Sahel drought emergency and mid-term ground water assistance in Mali	UN	07/73	01/77	350,000 6/		(***)
NER-73-007	Sahel drought emergency and mid-term ground water assistance in Niger	UN	07/73	01/77	420,000 6/		(***)
UPV-73-013	Sahel drought emergency and mid-term ground water assistance in Upper Volta	UN	07/73	01/77	500,000 6/		(***)
CHD-51-510	Sahel drought emergency and mid-term ground water assistance in Chad	UN	07/73	01/77	645,000 6/		(***)

1/ Participants: Kenya, Uganda and United Republic of Tanzania.

2/ Participants: Dahomey and Togo.

3/ Participants: Guinea, Mali, Mauritania and Senegal.

4/ Participants: Cameroon and Chad.

5/ Participants: Cameroon, Chad, Niger and Nigeria.

6/ Approximately, including UNICEF complementary assistance.

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ANNEX II

Summary data on some potential dam sites on major rivers

Senegal river

The dam planned on the Bafing river, a main tributary of the Senegal, at Manantali in the Republic of Mali, would provide a reservoir of 12 billion cubic metres, and would allow the regulation of the Senegal river flows up to a minimum of 300 m^3s. However, the regulation would be less during an initial phase, in order to manage artificial floods for after-flood cultivation.

The technical feasibility of the dam has been proved by the two UNDP projects. The site of Manantali was chosen after a careful selection. Two promising sites, Gouïna and Galougo, located on the main stream were discarded because of the high costs of the relocation of the town of Bafoulabe and of the railway situated in the reservoir area. The benefits of the regulation have been indicated by other UNDP projects: up to 400,000 hectares could be irrigated in the last stage of development; 100 MW can be provided at the Manantali hydro-power scheme.

The project is of interest to three countries: Mali, Senegal and Mauritania which are associated in the OMVS organization.

Niger river

The regulation of the Upper Niger flow in Mali will be provided by the Selingue dam constructed on a tributary of the Niger, the Sankarani. The reservoir will have a 2 billion cubic metre capacity. The regulation will remedy a very critical situation in dry years, as was the case over the three last years, and maintain a flow of more than 50 m^3/s in the Niger upper course. A pre-feasibility study of the dam has been completed. Financing is now seriously being considered by the European community and German bilateral assistance.

The benefits of the construction would be the irrigation of 40,000 hectares ensuring, in addition, the permanent supply of the large scheme of the "Office du Niger".

The installed capacity at the dam site would be 40 MW, which will be required for the supply of Bamako and Koulanga, a nearby town, from 1985 on. The regulation would also increase the production of other hydro-power schemes situated downstream from Selingue and in particular Sotuba, and in future Konie.

A considerable advantage of the regulation which cannot be calculated is again the provision of water into the Sahelian zone at the most critical time of the year. The large loop which the Niger river course makes to the north, "la boucle du Niger" is an internal delta where the river diversifies into a complicated network of lakes and branches extending downstream to the Tossaye sill, a natural rocky dam. During the flood period this region is almost completely

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submerged. During the low flow and after drying up by drainage and evaporation - large pastures remain which are the summer rendezvous for numerous migrating populations and herds. In addition to cattle breeding a main resource of the region is fishing.

The dam at Selingue will not be large enough to reduce the flood significantly, and therefore, will not impede the profitable inundation of the delta. But it will considerably increase the low flow discharge, thus providing the necessary water supply which has been missing these past years.

Downstream from Tossaye problems are different. As already stressed the flood peak is considerably delayed and only arrives in Niamey in March, in the middle of the dry season.

A project has been requested by the Governments of Mali, Niger and Upper Volta on this part of the Niger river course, the study of the development of the Liptako-Burma region. More specifically, as far as the Niger is concerned, a dam at the Tossaye sill would be studied. Its hydroelectric production could be used for the treatment of minerals existing in this sector (Manganese).

The Volta rivers

Only the black Volta belongs to the category of large rivers flowing from south to north into the sahelian zone. The other branches, the red and the white Volta flow southward and have only reduced discharges due to their feeding in a low rainfall and runoff zone.

A project has been suggested by the United Nations for the study of the over-all water resources development in the Upper Volta and for an integrated development study of the three Volta rivers for the water supply of Ouagadougou, irrigation, and eventually power production.

In addition the Volta river basin should be studied under a regional project which has also been suggested by the United Nations.

The Logone and the Chari rivers

These two rivers are most interesting examples of large rivers fed in the Guinean and Soudanese zones and bringing life into the Sahelian zone at the fringe of the desert. After merging at Fort-Lamy, they flow into Lake Chad, the waters of which are fresh and may be used for water supply and irrigation.

The Logone river flows within a most populated area (this is not the case for the Chari which was a no-man's land border in the past between two races and remains underpopulated.

Over a distance of 300 km, the Logone and Chari meander in a sequence of internal deltas, vestiges of higher levels of the Lake Chad waters. These plains

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are inundated in the flood season and offer satisfactory pastures during dry months. On the other hand the almost complete breakdown of the hydrological network makes it difficult to reclaim these plains for irrigated cultivation without regulation of the flow. A balance, therefore, has to be found between the conservation of favourable ecological conditions for fish reproduction and cattle breeding, and requirements for agricultural development.

Favourable dam-sites exist on the Wina river at Koumban and on the Pennde river at Gore, two main tributaries of the Logone.

A reconnaissance study has been carried out by the United Nations at these sites and a pre-feasibility study completed in 1968 to 1970.

The Governments of Chad and Cameroon are now interested in a more sophisticated investigation of the problem, and a request to UNDP is expected to be made.

An important result of water storage in the reservoir of Koumban (4 billion c.m.) and Gore (1 billion c.m.) would be the reduction of the flood and consequently decrease of the present evaporation losses in the inundated plains. Therefore a significant increase of the Lake Chad supply might be expected.

A diversion of some of the flow could eventually make possible power production at the Gauthiot falls on the Mayo Kebi (20 MW).

Economic Implications

The economic impacts of large river development in the Sahelian zone have been studied by the United Nations in connexion with the feasibility studies for the construction of three dams: Manantali, Selingue and Kouman.

The significance of such studies may be questioned, however, when they are not closely correlated with national or - better - regional economic planning on one hand, and integrated national or regional "water plans" on the other. For example, in one case plans for large-scale crop production have been drawn up without an in-depth review of potential markets. In the case of other schemes, the use of the same water resource has been envisaged simultaneously for different uses: a classic example is the Lac de Guiers which has been planned for three different uses: water supply of Dakar, Irrigation of the Richard Toll Casier and irrigation of the delta scheme. In fact, its capacity makes it suitable for one use only.

A second difficulty is that the calculated benefits are frequently interdependent. For instance, benefits from water-way transportation and from energy sales are dependent on agricultural and industrial (often agro-industries) development and mineral exploitation.

A last point is the unknown human factor. All projections for agricultural and industrial production will heavily depend on the speed with which local

people adapt to new ways of life and techniques, and are able to digest the intensive training imparted to them. Moreover, the incentive provided by higher earnings remains an open question.

Despite the above difficulties, the economic studies of the three schemes have been useful in finding which financing conditions and rates of development are required to ensure project feasibility.

For the Senegal river basin, according to a UNDP/United Nations report, final annual benefits would equal cost only 18 years after dam construction, despite a particularly favourable financing plan. Twenty years after the construction of the dam the benefits derived from agriculture (73,000 irrigated hectares at the time) would be $3.89 million; from navigation fees $1.60 million; and from energy sale $6.43 million. On the other side of the ledger, total financial charges for Manantali would be $7.3 million per year (investment cost $US 110 million). It must be stressed that the report does not foresee mineral exploitation and industrial development which would certainly enhance the feasibility, but were judged to be unrealistic by the subcontractor.

For the Sankarni-Niger river project at Selingue in Mali, benefits derive from 40,000 hectares of irrigated agriculture for which planned investment would equal approximately the same cost as dam construction, not including the power plant ($24.5 million against $27.0 million for the dam and $1.3 million for the power plant). Other benefits would result from energy sale, taking into account savings from replacing diesel power by cheaper hydropower. The benefit-cost ratio (benefit-cost/cost) has been assessed at 1.5. Some 12 years after the termination of dam construction the production would stabilize and then annual benefits would accrue as follows: energy sale $3.0 million, agriculture $4.5 million, navigation $0.09 million, fisheries $0.01 million. The annual cost for the dam would be $1.3 million. Benefits from navigation are small because of the dredging necessary to improve the river bed. Fisheries also have a small return because fish production is already plentiful in the Niger River's northern loop (cuvette lacustre) and the only saving would result from the more favourable location of the Selingue reservoir with respect to the market places (Bamako and southern foreign markets).

The costs and benefits from development of the Logone River have been evaluated in the final report for the project "Feasibility study for the diversion of the Logone River floods"; despite the UNDP/United Nations recommendations, the necessary study for a more precise evaluation has not yet been initiated). As a first phase of development the construction of the dam at Kouman on the Vina River appears to have special merit. The reservoir would store 3 billion m^3 available for irrigated agriculture, water supply, energy production and navigation. The cost of the dam has been evaluated at $22 million in 1969; the project cost would be approximately $30 million. The annual cost is estimated at 8 per cent of investment, i.e. $2.4 million per annum while the cost of regulated water would only be $0.08 mills per m^3.

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It appears that 30,000 hectares could be irrigated rapidly. Other benefits are expected from a power plant established at the Gauthiot Falls (30 MW) at Mayokeli using a small diverted flow from the Logone through the Toubouri Lakes. This energy would already be entirely consumed in Fort-Lamy, Bongor, Yagoua and Marota if it were available.

The fact that the economic feasibility of these three projects, taken as examples, can be easily challenged should not be a reason for abandoning their realization without further review. Even in more developed countries an assessment of the feasibility of such types of project has never been an easy task, particularly in situations where living conditions are expected to change drastically.